INTEGRATED RESERVOIR MONITORING USING SEISMIC AND CROSSWELL ELECTROMAGNETICS

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RESEARCH OBJECTIVES

The central problem in petroleum production is the development of a model or simulator that guides the drilling of wells, the management of the field, and the design of enhanced recovery processes. The objective of this research program is to integrate both seismic and electromagnetic geophysics for the mapping of reservoir properties between wells. This project will demonstrate that an integrated approach can be used to assign these properties to the flow simulation models of the interwell volume and greatly increase the effectiveness of in-fill drilling, reservoir production, and reservoir stimulation.

APPROACH

The project combines feasibility studies based on numerical models with the interpretation of field data to investigate possible methods of integrating electromagnetic (EM) and seismic data, along with well log information, to produce images of reservoir parameters (such as pressure and fluid saturations). Numerical studies have been carried out for a model of a producing North Sea oil field supplied by industrial partners. This study concentrated on well separations, which are relevant to offshore applications but have not been treated in field experiments to date. Two field data examples provided by industrial partners have been processed and interpreted to demonstrate how well log measurements, crosswell EM, and seismic data can be combined.

ACCOMPLISHMENTS

The numerical feasibility study of the Snorre Field demonstrates that crosswell EM could be measured and used to infer reservoir average water saturations in fields where well separations are on the order of 1 km. This represents an increase by a factor of 2 in well separations over what has been demonstrated to date in field measurements. This study demonstrated the necessity of integrating structural control from seismic data along with well control to provide the optimal estimates of reservoir water saturation in the interwell volume.

Crosswell, EM, and seismic field data from the Kern River and Lost Hills oil fields have been processed and interpreted. In the Kern River case, a detailed reprocessing of the seismic data to produce an equivalent CDP section between the wells was used to constrain the EM inversion for conductivity. This process increased the spatial resolution of the inferred fluid saturations as well as the correlation between logs and imaged fluid properties.

In the Lost Hills project, time-lapse seismic and EM data were able to predict both pressure and saturation changes in the inter-well volume. In addition, time-lapse changes demonstrated that small internal faults, not previously considered significant, were acting as barriers to flow. Figure 1 shows time-lapse changes in electrical conductivity, which directly maps changes in water saturation caused by an increase in oil.

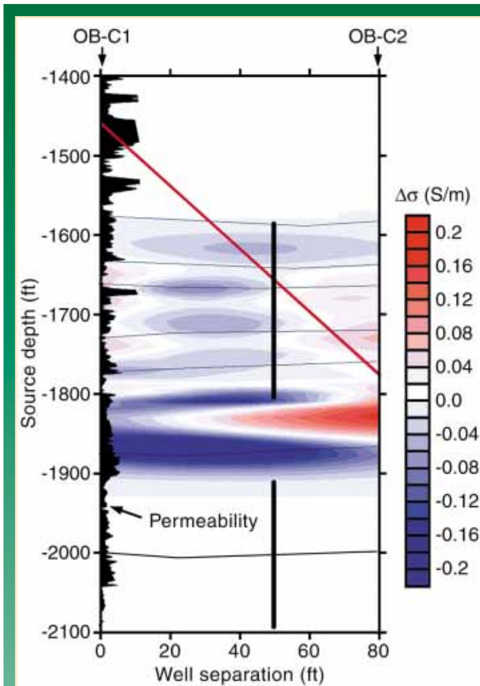

Figure 1. Time-lapse change in electrical conductivity during CO_2 injection. Large negative changes (blue) indicate an increase in oil saturation and correlate with high-permeability zones. The red line marks a small fault mapped from well logs. Changes in electrical conductivity truncate at the fault location.

SIGNIFICANCE OF FINDINGS

The addition of conductivity mapping via crosswell EM provides a robust estimate of water saturation changes that is independent from seismic data.

RELATED PUBLICATIONS

Hoversten, G.M., G.A. Newman, H.F. Morrison, and J.I. Berg, Reservoir characterization using crosswell EM inversion: A feasibility study for the Snorre Field, North Sea: Geophysics, 2001 (in press).

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